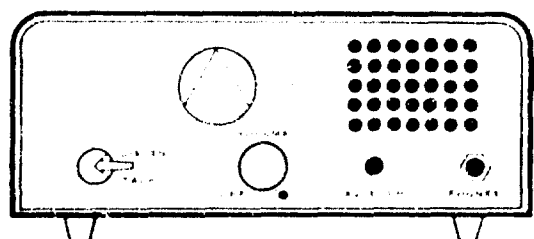


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STUDY
and
DEVELOPMENT
of
SPECIFICATIONS
for
PROTOTYPE TRANSMITTERS
and
RECEIVERS
for
FALLOUT SHELTER
COMMUNICATIONS SYSTEM



Office of Civil Defense
Department of Defense
Contract No. OCD-PS-64 &

Gautney & Jones
Consulting Radio Engineers
Washington, D. C.

STUDY AND DEVELOPMENT OF SPECIFICATIONS
FOR PROTOTYPE TRANSMITTERS AND RECEIVERS
FOR FALLOUT SHELTER COMMUNICATIONS SYSTEMS

Final Report
Contract No. OCD-PS-64-8

TGGM642

May, 1964

Submitted by:

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for

Office of Civil Defense, Department of Defense, Washington, D.C.

This report has been reviewed in the Office of Civil Defense and approved for publication. This approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense or of the various state and local civil defense organizations.

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ABSTRACT

This report describes a study approach to the problem of developing specifications for equipment for a radio backup to a landline fallout shelter communications system. Consideration is given those aspects of shelter programs which contribute requirements for electrical performance of the equipments. Discussions are included concerning frequency availability and usage, cost analysis, state of the art, recommendations, and the report includes full specifications for three types of radio equipment.

The conclusions reached during this study are that a radio backup to a landline communications system is technically feasible and a substantial savings in costs relative to that of presently available commercial radio equipment can be realized.

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ACKNOWLEDGEMENTS

We are particularly indebted to the representatives of the various semiconductor and equipment manufacturers who reviewed the tentative goals, furnished suggestions regarding construction requirements, and freely suggested possible approaches from the state of the art and cost standpoints. The names of the individuals involved are too numerous to list herein; however, the following companies were most cooperative in the project:

Motorola C & E, Incorporated, Chicago, Illinois

General Electric Company, Communications Products Department,
Lynchburg, Virginia

Farinon Electric Company, San Carlos, California

TRW Semiconductors, Incorporated, Lawndale, California

Motorola Semiconductor Products, Incorporated, Phoenix,
Arizona

Texas Instruments, Incorporated, Dallas, Texas

Communications Company, Incorporated, Coral Gables, Florida

Radio Corporation of America, Semiconductor Products Division,
Harrison, New Jersey

The Andrew Company, Chicago, Illinois

General Motors Corporation, Delco-Remy Division, Anderson,
Indiana

Credit is also due Mr. Henry Brown, Office of Civil Defense, for his helpful suggestions, and to the officials of Montgomery County, Maryland, who furnished information relative to the study area which is contained herein.

SUMMARY

This report concerns itself with, and results in, specifications for solid state transmitters and receivers particularly suited to the needs of fallout shelter communications by radio.

In order to evolve specifications for such equipment, certain basic assumptions are necessary concerning frequency availability, blast damage, available power, and radiation effects. It was assumed that frequencies in the Safety & Special Bands would be available, that no blast damage should be considered, that the equipment must operate from storage batteries as well as power mains, and that radiation presented no barriers to the use of solid state devices.

A prototype area was chosen to facilitate a general system concept, and documents relating to the aspects of shelter life which generate communications requirements were studied. Based on conclusions drawn from these endeavors, fundamental requirements concerning power output of the transmitters and receiver sensitivity in each band were established. A practical duty cycle was evolved from studying the day-by-day requirements for communications during the confinement period. This was related to battery drain, and practical allowable input powers were determined. Storage batteries were deemed particularly suitable for the standby power capability, and studies revealed that these devices were practical for the long-time storage requirements.

The evolution of general equipment requirements came about through a study of environmental conditions, Federal regulations governing the

operation of equipment in the specified frequency bands, and, of particular importance, the long-term maintenance requirements. These general requirements, in the main, dictate the physical characteristics of the equipments and such items as moisture absorption characteristics, corrosion, case design, connectors and plugs, and operating controls.

The magnitude and scope of the project when viewed on a nationwide scale are such as to militate against standardization of antennas and transmission line. An investigation was made, however, of commercially available materials, and it was concluded that antennas and lines are available to fit the needs of virtually every conceivable case on a broad scale.

The state of the semiconductor art, as applicable to RF power transistors, and manufacturing techniques were investigated in an effort to determine the cost and feasibility of equipments. Several manufacturers of equipment and devices were visited and lengthy discussions were held. There was unanimous concurrence in the feasibility of producing equipments in accordance with the general specifications. Semiconductor manufacturers furnished valuable insight into the question of device availability and cost. Based on these figures and other information, a cost analysis on each type of equipment was made.

It was concluded that the program is technically feasible, that equipments priced at less than half the cost of commercially available equipments can be obtained for the project, and that the specifications will lead to procurement of equipment which is suitable for use on a nationwide basis with but few exceptions.

A detailed set of mechanical and electrical specifications for equipment at 150 mc/s, 450 mc/s, and 950 mc/s is included.

CHAPTER I

INTRODUCTION

The concept for a national fallout shelter program allows for some means of communication between shelter management, the sheltered population itself, and higher echelons of civil authority. A previous study indicated that leased landline communication facilities were most practical for the purpose. The need for some means of back-up to this basic system is evidenced. Radio communication between echelons to be used when other means fail is a suggested solution.

1.1 STATEMENT OF THE PROBLEM

This report is in response to Contract OCD-PS-64-8 between Gautrey & Jones, Consulting Engineers, and the Office of Civil Defense, Department of Defense.

Article I, "Scope of Work," of the Contract defines the problem in the following terms:

A. The Contractor, in consultation and cooperation with the Government, shall furnish the necessary facilities, personnel and other services as may be required to study shelter facilities, communications components, equipment, techniques and systems, as specifically provided in this Contract and generally consistent with the Contractor's proposal dated May 31, 1963.

B. Specific Work and Services shall include, but not be limited to, the following:

1. Develop specifications for prototype radio transmitters and receivers, utilizing appropriate solid state techniques, and particularly designed for the operating and storage conditions and economy required for the shelter environment, and providing:
 - a. Operation in the region of 950 megacycles, transmitter output about 10 watts, suitable multiplexing.

- b. Operation in the region of 950 megacycles, transmitter output about 3 watts.
 - c. Operation in the region of 450 megacycles, transmitter output about 3 watts.
 - d. Operation in the region of 150 megacycles, transmitter output about 3 watts.
 - e. Operation in the region of 150 megacycles, transmitter output about 1 watt.
2. Develop a family of antenna and transmission line configurations suitable to the variety of environmental situations arising from the group shelter identification and stocking program throughout the Country.

1.2 ASSUMPTIONS

In any study which directs itself to those problems of a sheltered population in a post attack situation, certain basic assumptions are required to define those parameters of the instant situation which characterize the probable general conditions to be dealt with in the study.

In this specific study, some end point for design purposes must be designated, and the operational requirements for the equipments must be stabilized according to the basic assumptions at the limits which are dictated by economics and the basic needs.

A previous study of the Fallout Shelter Communications problem has been conducted (OCD-OS-62-123, Gautney & Jones, December, 1962). In this report, a basic landline system has been recommended as the most economical and practical first-line communications medium. The first assumption, therefore, is that the radio communications system will serve only as a standby or backup facility to that landline system. This is a pertinent

assumption from the frequency availability standpoint: however, the specifications for radio equipment must consider a condition wherein certain proposed landline circuits would be inoperative or non-existent.

A second assumption has been made concerning the availability of frequencies for this backup service. During the last several years, the expansion of 2-way radio facilities as an aid to municipal government operation has resulted in widespread distribution of frequencies throughout the United States in the Fire, Police, Highway Maintenance, and Local Government services. It is presumed that those communities which will seriously approach the problem of fallout protection for the population will probably have an existing radio network operating in one or more of the above services.

Assumption number three requires that there be no substantial blast damage within the structure in question from the standpoint of communications equipment. Obviously if there is fallout, a blast must have occurred somewhere. However, blast damage is beyond the scope of this report.

The fourth assumption which must be made concerns the available power for operation of electrical communications equipment. It must be assumed that, under conditions of fallout requiring the sheltering of the population, the personnel operating and maintaining power systems will also take shelter as required. How long the power systems may operate with less than full manpower is a matter for conjecture; however, certainly the power will eventually fail at the consumer location without adequate care of the equipment, switching at the power distribution points, and efficient supply of fuel.

Any equipment, therefore, designed for operation in a fallout shelter network must be capable of operation from emergency power sources as well as 115-volt AC power mains.

The final assumption concerns the effect of radiation upon solid state devices in electrical circuits. It is known that the characteristics of semiconductors are altered in the presence of high radiation fields. For the purpose of this study, it was assumed that, from the habitability standpoint, the possible radiation effect would be negligible. Radiation levels sufficiently high to render changes in the characteristics of the devices employed in the transmitters and receivers would certainly be beyond the human tolerance, thereby obviating the basic requirement for communications.

1.3 PROCEDURE FOR PROBLEM SOLUTION

In order to facilitate the conceptual design of an operational system, it was necessary to choose a prototype area of representative terrain, topography, and population density. This technique contributed a specific solution to a problem which could be fitted to the general problem on a national scale.

A suitable prototype must have an area of heavy population density, contain rural areas, have both flat and irregular terrain, and the area must be progressive toward Civil Defense and possess a plan for fallout shelter protection of the masses. Such an area is Montgomery County, Maryland.

Utilizing the prototype area and existing fallout shelter plan, a practical system was established which would afford an operational capability consistent with the requirements for communications as previously envisioned. By pinpointing the relative locations of shelter, precinct headquarters, area headquarters and other headquarters for administrative and managerial control, it was possible to make certain determinations regarding frequency usage, power outputs of the transmitters in the various frequency ranges, isolation of networks, antenna gain requirements and other general parameters of the subject equipments.

It was necessary to study those documents relative to communication requirements generated by a sheltered population, the likely environmental conditions prevalent during shelter occupancy, and other material which, while not directly applicable to the specific problem, did furnish a deeper insight into the overall problem of communicating during disasters and emergencies. In addition, the applicable Rules and Regulations of the Federal Communications Commission were studied to insure that the final specifications would procure equipment which was type acceptable and suitable for licensing in the appropriate services. These efforts made possible the drafting of a simple list of operational characteristics based on the background material studied and on certain system calculations which were made in the study area.

At this point, an investigation of the state of the art was undertaken. Magazine advertisements, trade periodicals, technical papers, brochures, and semiconductor specifications were perused for information regarding high-frequency, power semiconductors. In addition, members of our staff personally contacted manufacturers of semiconductor devices and communications equipment to discuss the state of the art at the engineering and application levels. Possible configurations for semiconductor lineups were discussed along with device costs on a "first-line" and "fallout" basis.* In this manner the feasibility of the project was determined.

Based on information from the semiconductor engineering and sales people, applicable costs figures for semiconductor complements were obtained. Equipment manufacturers were asked to provide "ballpark" figures

* A "fallout" device is a product which has failed to achieve all of the performance characteristics of a particular type but is still perfectly capable of being used in a circuit.

for construction costs based on existing product lines and in light of less restrictive requirements for the equipments in question. This information was correlated to form the basis of a cost analysis for each of the desired units.

1.4 CHANGES IN THE PROBLEM

In the course of making system calculations for the prototype area, it became apparent that certain of the contract stipulations regarding power and service required adjustment.

Available frequencies, state of the art, and isolation of networks presented barriers to the proposed equipment requirements which necessitated an engineering judgment regarding the feasibility of 10 watts at 950 megacycles and the proposed use of this frequency band for long path service. Subsequently, the requirement for 10 watts solid state at 950 megacycles was reduced to 1 watt with a realignment of the echelon service requirements. Moreover, an additional requirement for transmitters capable of approximately 3 watts output at 150 megacycles was obvious. This change in concept was reported in a quarterly progress report and, since no adverse comments were received from the Department of Defense, was adopted as a goal.

CHAPTER II

THE SYSTEM CONCEPT

2.1 INTRODUCTION

In order to evolve specifications for equipment which will achieve the desired inter-shelter communications requirements satisfactorily, it is necessary to make a preliminary system study for a representative area. Consideration must be given to frequency availability, geometric locations of fallout shelters or the various echelon control headquarters, and the factors which influence radio frequency transmission such as path length and topography. An analysis of these facets will enable recognition of the generalized equipment requirements.

Such a study will be discussed in this chapter. It must be emphasized, however, that many of the conclusions reached regarding specific requirements for the study area may not be applicable to other parts of the country. In addition, it will be recognized that a complete, detailed system design has not been made, but rather a cursory treatment to facilitate the ultimate goal of this report -- the development of specifications. Nevertheless, a satisfactory system can be designed using the basic equipments with the specifications recommended herein.

2.2 FREQUENCIES AVAILABLE FOR FALLOUT SHELTER COMMUNICATIONS

One of the more critical problems involved in the concept of fallout shelter radio communications is the availability of frequencies for the purpose. The principal difficulty arises from the fact that the equipment will be activated for drill purposes and tests. Since certain exercises will be conducted during non-emergency periods for training purposes, the transmitters must be licensed by the Federal Communications Commission.

Therefore, frequencies must be chosen on which communications concerned only with the Civil Defense operation of fallout shelters are authorized when emergency conditions are non-existent.

The matter of licensing the equipment by the Federal Communications Commission, raises a question concerning the eligibility of the licensee. It is apparent that the only practical way to insure efficient, organized employment of radio equipment for fallout shelter communications is to place the equipment in the hands of a local government such as a town, city, county, or state. Such licensees are authorized to carry out communications concerning the various phases of governmental responsibilities in the Safety and Special Services bands.

The present regulations of the Federal Communications Commission concerning the allowable traffic in the Public Safety services require that frequencies allocated for use by Police jurisdictions be used exclusively for police business. The same restriction prevails for Fire and Highway Maintenance allocations. Communities which are too small to support separate communications facilities for each of the services, but which require communications for the good operation of the Government, may make use of those frequencies allocated for Local Government use. In this service, traffic concerning any phase of the Government operations may be passed. This, of course, includes Civil Defense messages and requirements.

These restrictions essentially require that this equipment be licensed in the Local Government Radio Service of the Safety and Special Radio Services which is covered by Subpart E of Part 89 of the Rules and Regulations of the Federal Communications Commission.

Frequencies are allocated in this service in all portions of the spectrum set forth in the contract. In addition, many larger communities, where

allocation of additional frequencies may be difficult, already have authorizations for stations in this service; and a communications system for fallout shelters could be designed, to a large extent, around those existing frequencies.

The operational problems inherent in conducting drills and tests could then be alleviated by arranging to have these practice operations occur on weekends when normal traffic relative to the Local Government business is minimized, if existent.

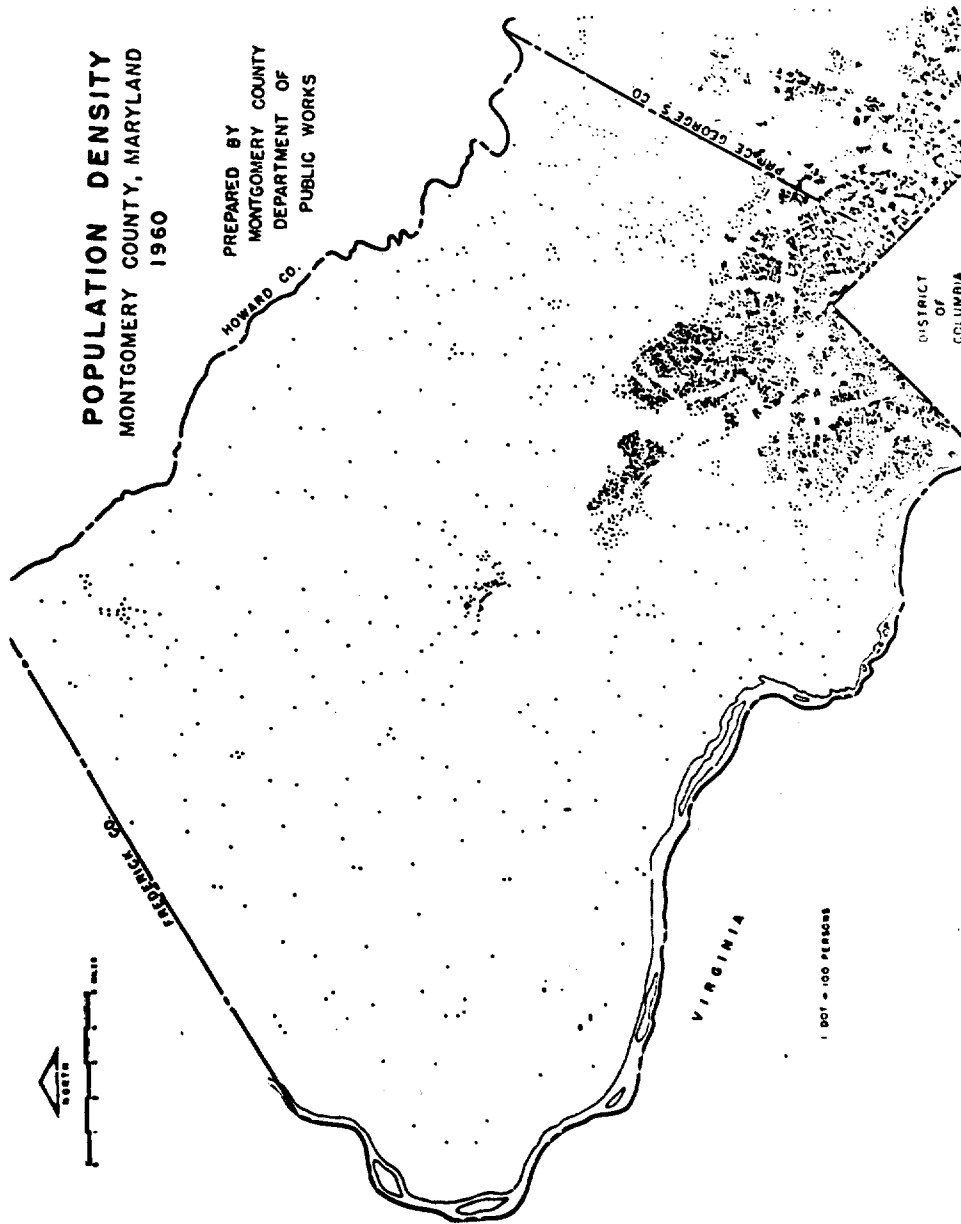
2.3 THE STUDY AREA - MONTGOMERY COUNTY, MARYLAND

Montgomery County, Maryland, is a part of the Washington D.C.-Maryland-Virginia metropolitan area and is contiguous to a portion of the District of Columbia. As a result of this geographic position, the southeast part of the County has an urban nature and highly concentrated population distribution. The County is bounded on the north by predominantly rural Howard and Frederick Counties, and it follows that the northern portion of Montgomery County, Maryland, is rural in nature demographically and geographically.

The County approximates a trapezoid in shape with its major dimension running from the northwest to the southeast. It is roughly 26 miles long and 22 miles wide, containing an area of 493 square miles.

Topographically, the area is composed of low rolling hills, and its elevation rises from less than 50 feet AMSL at the Potomac River on the South to 850 feet in the area of Damascus to the North.

According to the 1960 Census of the United States, the population of Montgomery County is nearly 341,000, of which almost 90 per cent reside in an area which is less than 10 miles from the District of Columbia boundary.



The attitude of the County toward Civil Defense measures is considered very progressive. An underground Emergency Operating Center which will house the County Government during periods of emergency has been constructed in Rockville, the County Seat, and is now operational. Further, all of the County's communication control facilities for Police, Fire, Highway Maintenance, Local Government, and Civil Defense are contained in the Center. One of the major features of this Center is its use for the day-to-day operations of the County Government communications networks. Should an emergency arise without warning, the communications centers are fully staffed to handle the normal traffic loads. Moreover, the necessity of familiarization with a new environment at the time when the emergency occurs has been eliminated.

Of perhaps more importance to the immediate project, the Civil Defense authorities have evolved a shelter plan for the population selecting, for the most part, County-owned buildings as the sites for future fallout shelters. An organizational structure has been set forth which relates Civil Defense echelons to existing political subdivisions, such as districts and precincts. The advantage of such a structure is obvious. The adult population is familiar with these political subdivisions from the registration and voting procedures, and educational requirements are minimized in the light of prior familiarity. A map showing the Civil Defense Districts is included for clarification of this discussion.

For communications purposes, obviously these political subdivisions must be further expanded to include subjacent control responsibilities depending upon population density and/or traffic volume. The general configuration of responsible subdivisional headquarters is pyramidal with each echelon control point responsible for the safety, welfare, and good order of the subordinate control points reporting to it.

For Montgomery County, the problem is greatly simplified by devising nomenclature for identification of echelon levels as follows:

County (Emergency Operating Center, Rockville)

District (13 election districts)

Area (combinations of precincts in heavily populated areas)

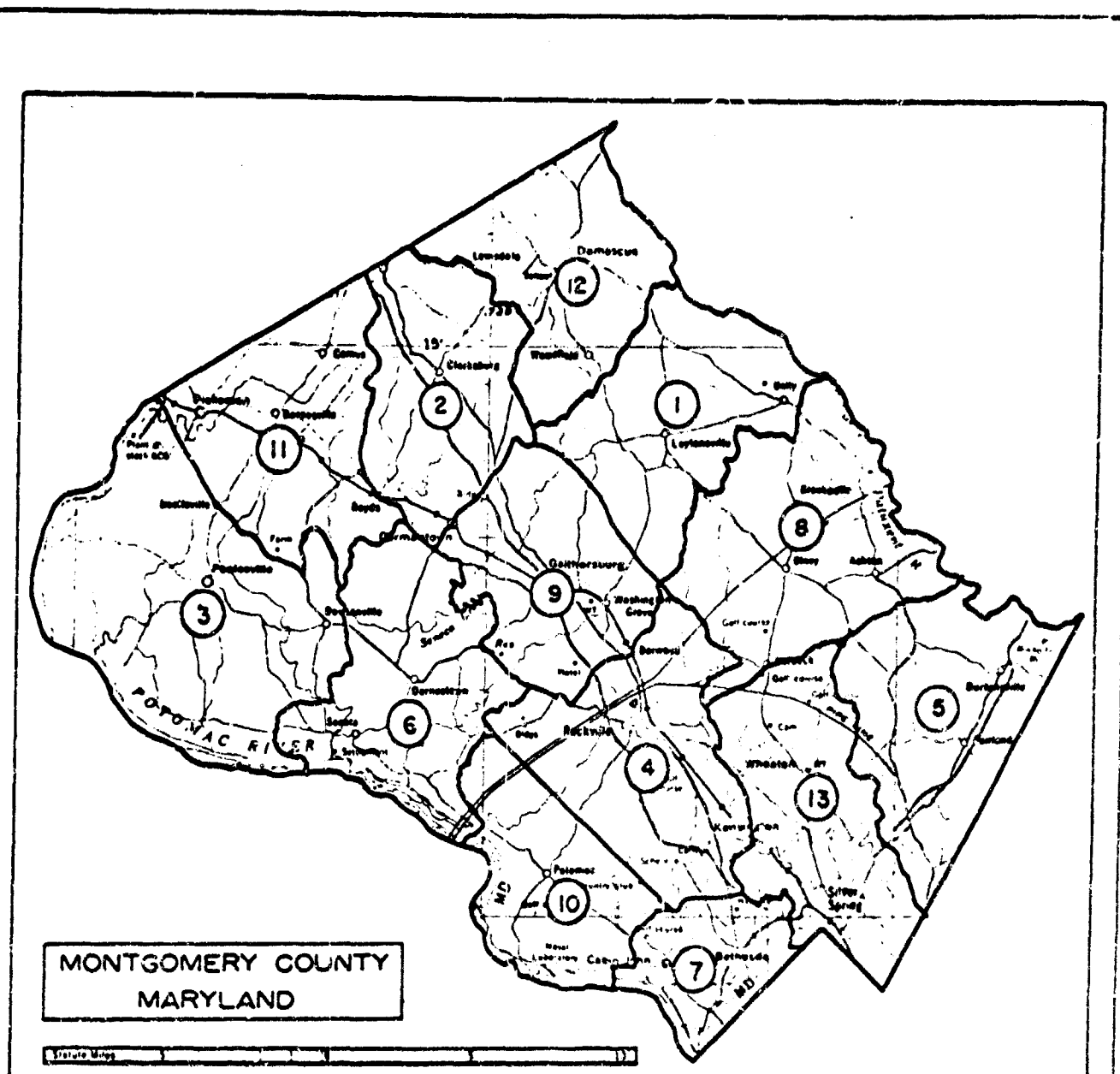
Precinct (87 voting precincts)

Shelter (fallout shelters in sufficient numbers to house the population)

It is felt that similar nomenclature will be useful and applicable to the national problem. Heavily populated areas will require all of the subdivisions listed. Less densely populated areas will find it feasible to employ fewer echelons. Montgomery County affords examples of both situations in question.

The rural districts of Laytonsville, Clarksburg, Poolesville, Potomac, Barnesville, and Damascus do not require area or precinct control echelons. On the other hand, the semi-urban districts of Rockville, Colesville, Larnestown, Olney, and Gaithersburg do not require area echelon control due to the small number of precincts involved.

The lengths of the transmission paths over which radio communication must be achieved are subject to variation due to varying population density and echelon level. For instance, from County to District Headquarters the distances range from 5 to 15 miles in Montgomery County. From District to Area in the urban cases, and from District to Shelter in the rural areas, the transmission paths vary from 1 to 4 miles in length. The distances between Area and Precinct and between Precinct and Shelter echelons lie in a range of from less than 1 to 3 miles.



CIVIL DEFENSE DISTRICTS

- | | |
|-----------------|-----------------|
| 1. LAYTONSVILLE | 8. OLNEY |
| 2. CLARKSBURG | 9. GAITHERSBURG |
| 3. POOLESVILLE | 10. POTOMAC |
| 4. ROCKVILLE | 11. BARNESVILLE |
| 5. COLESVILLE | 12. DAMASCUS |
| 6. DARNESTOWN | 13. WHEATON |
| 7. BETHESDA | |

2.4 TRANSMISSION PATH LENGTH VS FREQUENCY USAGE

Under the original radio back-up system concept, from which the instant contract evolved, the use of a frequency for communications was rigidly related to a control echelon rather than to transmission path length. It must be pointed out, however, that this earlier report concerned itself mainly with a generalized discussion of communications with primary emphasis on a landline system for a prototype area.

When the problem is viewed on a national scale with the fundamental interests being the most efficient use of radio equipment and frequencies, it becomes much more practical to think of using the lower frequencies for the transmission paths of the longest length. On the basis of free space attenuation alone for the 15-mile paths listed above, it would require 10 times as much radiated power at 450 megacycles and 40 times the power at 950 megacycles to achieve communications than would be necessary at 150 mc/s.

In the upper level echelons, path lengths begin to increase, and a requirement also exists for communications between several control points at the same echelon level. In most cases, this precludes the use of directional antennas, thereby limiting the power gain available through antenna configuration alone. Assuming, however, that a 10 db omni-directional gain in the horizontal plane could be realized, it would still require 12 times as much input power to the transmitter to make up the remaining deficiency at 950 megacycles considering achievable operating efficiencies. Obviously, such uneconomical use of the input power would be intolerable when operating from standby emergency power supplies.

On the other hand, in the congested areas of short path lengths where network isolation is of major concern because of a general lack of an adequate number of frequencies, the use of 950 megacycles would inherently

include a reduction factor of 40 which could be increased readily through the use of directional antennas.

These factors dictated a change in the basic problem. It is now apparent that frequency usage must be related to path length and isolation requirements. Adopting this concept, the transmitter output powers can be reduced, the emergency power supply requirements can be relaxed, and a more efficient and economical system can be designed for any given area. Therefore, communications for path lengths approaching 15 miles would utilize frequencies in the 150 mc band, regardless of echelon level. For intermediate path length, 450 megacycles would be used; and for short distances of 3 miles and less, 950 megacycles would be chosen for densely populated areas. The choice of frequencies, however, would be closely tied to frequency allocations for the area.

2.5 SYSTEM CALCULATIONS

System calculations have been made to determine the minimum performance characteristics of the equipment in each frequency band based on information gathered in studying the prototype area. In making these calculations, certain assumptions have been adopted concerning the proposed antenna heights, transmission line lengths, transmission path conditions, and the type and quality of antennas and transmission line which may be used in any system. These assumptions direct themselves to the predicted average conditions, realizing that the individual situation may vary considerably and require adjustment.

An antenna height of 20 feet has been assumed for all of the calculations. Since most of the fallout shelters specified in the study area are public buildings (many are schools), it is reasonable to expect that the roofs of these buildings will be at an average height of 30 feet above ground level.

Higher elevations will enhance and lesser elevations will degrade the transmissions over a given path, but it is felt that this is a logical average from which to make general calculations.

The average transmission line length considered in these computations is 100 feet. If the shelters are located in the basements of buildings having a rooftop elevation of 30 feet, the total vertical length of line should not exceed 45 feet. This allows a total of 55 feet for horizontal displacement of the antenna or radio equipment.

In all of the calculations, the existence of a line of sight between transmitting and receiving antennas has been assumed and corrective loss factors have been added to approximate average conditions. In certain areas of extremely rough terrain, some adjustment of the results would have to be made. However, for the purposes of determining necessary equipment performance for a national stocking program, this assumption is valid recognizing that corrective action in special cases will be required to compensate for irregularities in the terrain of a specific area.

With respect to the types and quality of antennas and transmission lines, examination has shown that equipment with characteristics similar to those of the products commercially available at the present time will be suitable for employment in the sample system. The available gains and pattern characteristics of today's antennas will satisfy the requirements of the system concept. Of course, the duties of certain of the organizational echelons preclude the use of antennas with directional characteristics. In addition, the excessive attenuation of high frequencies, such as 950 megacycles, militates against the use of certain types of transmission lines in connection with critical paths. In the main, however, gain and attenuation characteristics

of commercially available products have been assumed to be satisfactory for the purpose of these calculations.

One of the factors which must be given careful consideration is the degradation in performance characteristics of the equipment during the storage period. It is recognized that this equipment must be used for drills and training exercises, and it follows that some degradation will occur. Moreover, the quality of maintenance in some cases may leave much to be desired. Therefore, a compensating factor has been used in these calculations. This factor allows for a reduction in the transmitter power output and a reduction in the receiver sensitivity to 50 per cent of their rated values.

The following pages show sample calculations for the longest transmission paths encountered in the study area. Equipment characteristics which will satisfactorily provide communications over these paths are also shown.

SAMPLE CALCULATIONS

Frequency:	150 megacycles
Path Length:	15 miles
Antenna Height:	30 feet = 4.6λ
Path Structure:	132 db
Transmission Line Loss (Xmtr):	1.5 db
Transmitter Degradation:	3.0 db
Transmission Line Loss (Rcvr):	1.5 db
Receiver Degradation (Power):	<u>3 db</u>
Total System Loss:	141 db
3-Watt Transmitter:	4.8 dbw
Horizontal Gain Antenna (Xmtr):	5.8 db*
Power Delivered to Receiver Terminals:	-130.4 dbw
Required Receiver Sensitivity:	2 uv
*Relative to a half-wave dipole	

Frequency:	450 megacycles
Path Length:	10 miles
Antenna Height:	30 feet = 13.7 λ
Path Attenuation:	126.0 db
Assumed Shadow Loss:	10.0 db
Transmission Line Loss (Transmitter):	1.9 db**
Transmitter Degradation:	3.0 db
Transmission Line Loss (Receiver):	1.9 db**
Receiver Degradation:	<u>3.0 db</u>
Total System Loss:	145.8 db
3-Watt Transmitter	4.8 dbw
Horizontal Gain Antenna (Transmitter):	5.8 db*
Horizontal Gain Antenna (Receiver):	5.8 db*
Power Delivered to Receiver Terminals:	-129.4 dbw
Required Receiver Sensitivity:	2.4 uv

*Relative to a half-wave dipole

**Higher quality transmission line would be used for this longer path.

Frequency:	450 megacycles*
Path Length:	4 miles
Antenna Height:	30 feet = 13.7λ
Path Attenuation:	109.0 db
Assumed Shadow Loss:	10 db
Transmission Line Loss (Transmitter):	3.8 db
Transmitter Degradation:	3 db
Transmission Line Loss (Receiver):	3.8 db
Receiver Degradation:	<u>3 db</u>
Total System Loss:	132.6 db
1-Watt Transmitter:	0 dbw
Horizontal Gain Antenna (Transmitter):	5.8 db*
Unity Gain Antenna (Receiver):	0 db*
Power Delivered to Receiver Terminals:	-126.8 dbw
Required Receiver Sensitivity:	3 uv

*Relative to a half-wave dipole

Frequency:	950 megacycles
Path Length:	3 miles
Antenna Height:	30 feet = 29 λ
Path Attenuation:	103.0 db
Assumed Shadow Loss:	20.0 db
Transmission Line Loss (Transmitter):	2.9 db
Transmitter Degradation:	3.0 db
Transmission Line Loss (Receiver):	2.9 db
Receiver Degradation:	<u>3.0 db</u>
Total System Loss:	134.8 db
1-Watt Transmitter:	0 dbw
Unity Gain Antenna (Transmitter):	0 db*
Directional Antenna (Shelter):	10 db*
Power Delivered to Receiver Terminals:	-124.8 dbw
Required Receiver Sensitivity:	4 uv

*Relative to a half-wave dipole

CHAPTER III

GENERAL EQUIPMENT REQUIREMENTS

3.1 INTRODUCTION

The calculations shown in the previous chapter give a general indication of the transmitter powers and receiver sensitivities necessary to provide communications within the study area. In order to completely specify the general requirements, however, consideration must be given to the environmental conditions to which the equipment will be subjected; the additional requirements imposed upon the transmitters and receivers due to operational difficulties, government regulations, and cost; the type and quality of antennas and transmission lines to be included in a system design; and finally, the most feasible source of emergency power to insure operation for the period of confinement in the event of commercial power failure.

3.2 REQUIREMENTS CAUSED BY ENVIRONMENTAL CONDITIONS

Initial consideration of the environmental conditions posed some operational and storage requirements necessitating rather costly approaches. A thorough analysis, however, of the temperature and humidity records throughout the United States based on the normal and extreme shows that minor precautions in construction practices coupled with Federal regulations concerning transmitter operation will suffice to insure that physical storage and operational environments will not materially affect the capabilities of the equipments.

The Federal Communications Commission requires that equipment operating in the bands of frequencies under consideration for a fallout shelter communications network have a frequency stability over a wide range of temperatures. In properly designed shelter space, assuming adequate cubic

space per person or air exchange in lieu thereof, no problems are anticipated in maintaining operation of the equipment from the standpoint of temperature.

Humidity, however, may pose some restrictions on materials utilized in construction. Consideration must be given to the storage period and the possible conditions existing in the assigned spaces. Many of the shelter areas will be basements of buildings which have no means of humidity control. Assuming dampness to be prevalent in many locations, consideration of the long-term absorption rates of coil forms, etched board substrates, etc., will be an important factor in the overall design. Obviously, the use of paper coil forms will be precluded and certain of the printed board substrates will be disqualified. This does not mean, however, that glass boards are indicated or desired due to basic cost considerations. Certainly hermetic sealing of the cases is not required. With suitable moisture-proofing of the boards, care in the choice of coil forms, components, and loud-speaker cones, the equipment should withstand relative humidities approaching 100 per cent without damage or degradation.

The human aspect of environmental conditions during the emergency confinement period will require equipment configurations which otherwise would not be considered. It cannot be expected that trained operators will be available from among the sheltered population. In fact, the equipment should be so designed mechanically that its operation is obvious. If possible, it should resemble a piece of equipment which is familiar to most people. To have the equipment designed to resemble a telephone is not practical from the mechanical standpoint. Most people, however, are somewhat familiar with the common office intercom either through experience, movies, television, or personal observation. This configuration, moreover, lends

itself well to the mechanical problems involved in construction, storage, and use. It is not considered wise, for example, to have a separate microphone with the units. There are advantages to be gained from a separate microphone. Chiefly, these advantages concern the ease of operation. The principal disadvantages are the fragility of the cable, possibility of theft, and, perhaps most important, the unit can be allowed to fall and sustain damage which would render the entire unit inoperative. Therefore, a microphone which is enclosed within the unit housing seems indicated.

Ambient noise levels within the shelters cannot be determined. It is imperative, therefore, that some type of earpiece be available to enhance the possibility of hearing and understanding the transmitted intelligence. It may not be desirable from the psychological standpoint to have all messages heard by the passers-by. It is anticipated that the action of using the earpiece will silence the loudspeaker. Aside from the possibility of a psychological requirement, another advantage in conservation of power will be gained during the times when the earpiece is utilized.

3.3 MAINTENANCE REQUIREMENTS

Other general requirements for the equipment are dictated by other than environmental conditions. One of the major items of concern in the design of equipments which will possibly be installed in large numbers is the maintenance problem. While many of the jurisdictions which may possibly install fallout shelter communications will have adequate maintenance staffs capable of utilizing test equipment and effecting repairs, many will not be so fortunate.

In our investigation of the general construction program for the equipments outlined in this report, consideration was given to the modular concept. This, of course, allows for basic testing and removal of defective

circuits by relatively inexperienced maintenance personnel. The added cost to the engineering and construction does not seem to warrant such an approach. The equipment will be sectionalized insofar as practicable and commensurate with good engineering practice. Beyond this, an economic barrier exists.

Those concessions to maintenance simplicity, aside from the mechanical layout of components and housing, will be limited to external metering at a common point with emphasis on a "go, no go" type of readout. This will allow a routine maintenance check without the necessity of entering the equipment enclosure, and can be accomplished with relatively inexperienced personnel.

Moreover, the inherent reliability and long life of transistorized equipment offers maximum relief to those responsible for maintaining a large system. It is expected that adequate maintenance can be maintained utilizing the above concept of testing and a 1 per cent spare unit stocking program for each type of equipment installed. Under this concept, a determination will be made concerning the operational capability of the equipment. Either it will be within system design limits or it will not. If it does not meet the requirements for the system design, it will be totally replaced and the defective unit returned to a central maintenance point for repair.

3.4 REQUIREMENTS FOR MULTIPLEX TECHNIQUES

One of the contract requirements concerns itself with multiplexing techniques. Our studies have indicated that there is no need for widespread use of multiplexing equipment. The expected traffic loads within the pyramidal structure are such that multiplexing will not be required in any but unusual cases. In the largest metropolitan areas of the United States, it is possible that additional echelon control points will be required.

In such cases, a need for multiplexing can be foreseen between the overall headquarters location and subordinate headquarters in various sectors of the area acting as distribution points much in the manner of general headquarters in lesser populated areas. In these instances, justification exists for the use of multiplex techniques. Such justification could only be determined, however, through a careful analysis of the specific system requirements.

Since the need will be extremely rare and will require specially designed RF equipment for the purpose, it is economically unfeasible to continue further consideration. Transistorized equipment exists and is commercially available which makes use of multiplex techniques. A few of the manufacturers are currently investigating the use of semiconductors at 960 mc for multi-channel equipment. Notwithstanding the possibility of commercially available semiconductor transmitters and receivers for this frequency, it is felt that centers large enough to require multi-channel operation to accommodate the traffic load will, in all likelihood, be large enough and of sufficient importance to the overall system to warrant standby emergency generator capability, thus relieving the emergency power supply requirement inherent in the use of this type of equipment. Specifications can be drafted for this service on a case-by-case basis for the specific system which will allow procurement of commercially available equipment from a sufficiently large number of manufacturers to make it economical to utilize this approach.

3.5 TRANSMITTER AND RECEIVER REQUIREMENTS

As shown in the calculations in the preceding chapter, transmitter output powers of 3 watts at 150 mc, 1 or 3 watts at 450 mc and 1 watt at 950 mc will be suitable in nearly all cases for the fallout shelter communications systems. In those instances where higher powers are necessary, the effec-

tive radiated power can be augmented by utilizing antennas which offer horizontal or directional gain characteristics. This is a far more suitable economic solution than developing equipments which are capable of generating higher outputs directly.

One of the more significant factors governing the remaining electrical specifications for the transmitters is type acceptance by the Federal Communications Commission. Certain fundamental operating characteristics have been established and incorporated in the Rules and Regulations of the Commission. One of these characteristics concerns the stability of the carrier frequency. In equipment wherein the input power to the amplifier exceeds 3 watts, the frequency must be maintained within .0005 per cent between -30° C and $+50^{\circ}$ C. In a literal sense, each of the equipments for which specifications have been drawn will require more than 3 watts input to the final power amplifier. It is true that at the higher frequencies the input to the final stage will be pure RF with no DC power input; but, to our knowledge, no interpretation of this ruling with respect to passive multiplier stages has been made. The specifications, therefore, will require .0005 per cent tolerance throughout the temperature range specified.

Other specified requirements include the minimum acceptable attenuation of spurious and harmonic emissions, the maximum allowable frequency deviation and bandwidth, and the highest permissible modulating frequency. These requirements are entirely consistent with the operating requirements established in our studies of a prototype system. They appear to be neither overly restrictive nor inconsistent with the overall goals.

As mentioned before, an external microphone is considered a possible source of failure due to environment and storage conditions in the sheltered areas. In addition, the equipment will be made as simple to physically

operate as it is possible to design. The external controls will consist of a "push-to-talk" lever which controls a wiping switch for voltage switching between transmitter and receiver. This will eliminate the necessity for a relay with possibly exposed contacts which are subject to corrosion during storage.

The off-on switch will be incorporated with the volume control to approximate as closely as possible an ordinary radio control. Since the setting of any squelch controls affect the basic sensitivity of the receiver, it is planned to place this control either inside the case of the unit or to make it a screwdriver adjustment. Some means of indicating that the set is operational during the transmit phase will be needed. This could possibly be a lamp indication or an inexpensive meter marked in the conventional red, yellow, green mode to indicate not working, working at less than full output, and normal operation respectively. Such a device, while not necessary to the operation of the site, would offer some measure of intelligence to the operator regarding the condition of the unit.

The problem of background noise enters the picture with regard to transmitter specifications. This factor will be compensated for by circuitry which will inhibit modulating signals at a level lower than the level of a normal conversational voice at a distance of 3 feet from the built-in microphone.

The receiver requirements, as derived from system calculations, are not stringent when compared to equipment presently available commercially. Receiver sensitivities of 1 uv, 2 uv, and 4 uv at 150 mc, 450 mc, and 950 mc respectively, will be satisfactory for use in a fallout shelter communications system.

Since it seems likely that little high power mobile activity will be taking

place during the first few days of confinement and considering the low output power levels contemplated for the equipment in the shelter system, the selectivity requirements of the receiver may be relaxed somewhat. Adjacent-channel interference will not be the problem it is during normal periods. Again, it is anticipated that tests and drills will be conducted during periods when the problem of adjacent-channel interference will be lessened as always happens during slack communication periods.

The primary interest in the back-up fallout system is to convey voice intelligence on a point-to-point basis. No unusual fidelity will be required. Moreover, tests conducted by Bell Laboratories have defined the limits of destruction of intelligence when certain frequencies are suppressed or when distortion is present. In light of the basic goals, the requirements for frequency response and distortion of the audio signal may be less stringent than that commercially available today. By relaxing these requirements while still maintaining the required tolerances in the system, some savings can be realized in construction.

In the design of two-way mobile communications equipment and associated base station equipment, the manufacturer must take into consideration the motion of the mobile radio unit. The common practice is to utilize a discriminator with perhaps two stages of limiting ahead of it to compensate for the rhythmic fading predominant in this type of operation. The back-up system for fallout shelters will be a point-to-point network. There will be no widespread need for direct mobile-to-shelter operation. The receivers may be designed, therefore, with a ratio detector, thus eliminating the need for excessive limiting in the preceding stages. This will result in fewer components and lower cost. It is possible that squelch circuits may become slightly more involved with the elimination of limiters.

but not sufficiently to materially affect this cost saving feature.

In the section dealing with environment, mention was made of background noise and its possible effect in signal reception. One aid in combating this problem is the use of an earpiece. It was shown that this also reduced the input power since current drain increases with an increase of volume output. Another power saving technique is to specify the audio power output of the receiver in terms of acoustic power rather than electrical input power. In this manner, the manufacturer may use a more efficient transducer, resulting in less electrical power consumption while still achieving the ultimate goal of adequate sound level for receiving and understanding voice intelligence. If the transducer is of good quality, it may also satisfy the requirements for a microphone, thus eliminating still another component in the unit.

3.6 REQUIREMENTS FOR ANTENNAS AND TRANSMISSION LINES

For purposes of preliminary system calculations, it was assumed that no requirements existed for power gain or directivity exceeding those commercially available in standard configurations. Typical gain and attenuation figures of some of the antennas and transmission lines were used in the computations. This was done in order to determine the required electrical characteristics of the transmitters and receivers in each band of frequencies.

A thorough examination of the mechanical requirements of lines and antennas has been made in light of the possible environment during storage periods as well as those environmental conditions which might exist in the moments immediately following a blast.

One of the basic assumptions for the purpose of this report is that no blast damage exists, and fallout radiation hazards have been the major con-

sideration in the basic resolutions regarding equipment characteristics. However, it is considered of particular importance to determine the capability of antennas to withstand the effects which follow a nuclear explosion. These capabilities, however, must be viewed in the light of certain factors concerning the mounting structures and locations which tend to place a finite limit on the ultimate requirements.

Today's communications antennas are designed to withstand wind velocities of between 100 and 125 miles per hour while loaded with 1/2" of radial ice. In 1955, tests were conducted in Nevada to determine the blast damage to commercially available antennas of a similar type to those used in the calculations. It is interesting to note that these antennas withstood an overpressure of 5 PSI and sustained no damage detrimental to continued operation.

The vast majority of the buildings designated as shelters in the study area are unreinforced brick and masonry construction. It is our presumption that this will prove to be the case in most of the nation. It is reasonable to assume that buildings of this construction will not retain any measure of habitability as fallout shelters following overpressures of 5 PSI. To specify antennas with mechanical ruggedness beyond those commercially available is to place an unwarranted economic barrier in the path of ultimate implementation of the program.

Presuming that the ability to withstand 5 PSI is the maximum mechanical requirement for antennas, an investigation was undertaken to determine the minimum mechanical ruggedness which would be acceptable for the probable environmental conditions. The record wind velocities for 45 cities in 31 states were collected. Of these, the minimum was 49 miles per hour (true value) recorded at Cincinnati, Ohio. The velocities range from this

through 132 miles per hour recorded at Miami, Florida. Only four cities recorded less than 60 miles per hour as a maximum with the majority exceeding 70 mph.

If these wind velocities are translated into terms of winds accompanying overpressures, it is easy to see that the average overpressure requirement is in excess of 2 PSI. Antennas can be designed which will fit the minimum ruggedness requirements. This, however, requires a developmental program and results in an entirely new line of equipment which would find little application commercially. While the cost of materials for the individual antenna would be less than those commercially available, no real savings could be realized unless quantities in the thousands were to be purchased. Information from antenna manufacturers indicates that commercial types of antennas would reach an agreeable price break at a smaller quantity figure and would not entail a developmental and engineering project.

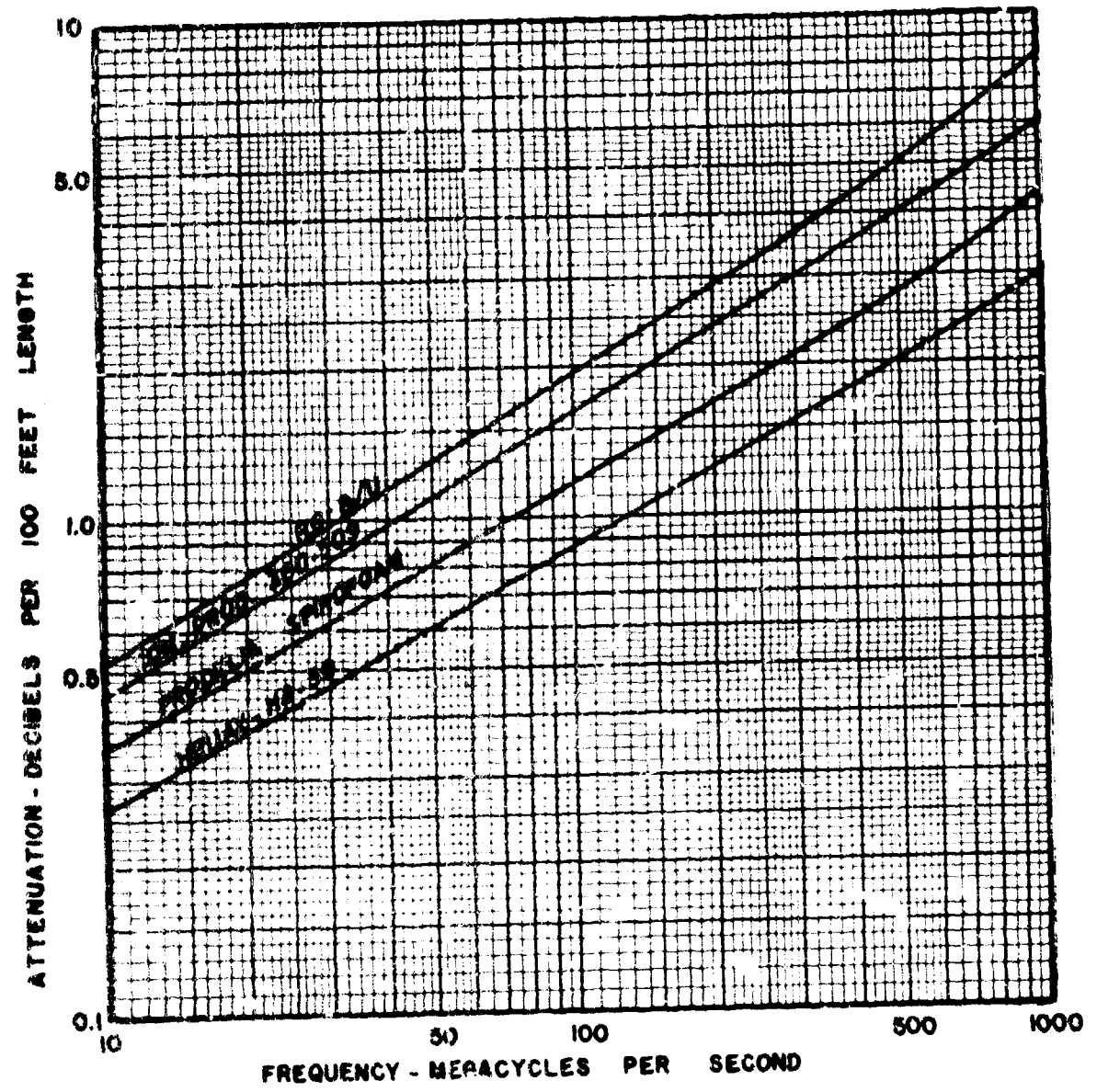
Antennas are readily available which are omnidirectional in the horizontal plane but directional in the vertical plane. This configuration results in "squeezing" of the radiated energy and gives an apparent power gain when compared to a half-wave dipole. Antennas offering from 0 to 6 db gain at 150 mc and from 0 to 10 db at 450 mc and 950 mc can be obtained from a number of manufacturers at a variety of prices. Directional antennas are available with power gains ranging from 3 db for the familiar cardioid to 10 db for the dual Yagi and reflector types of antennas. From the electrical and mechanical standpoints, it appears that antennas are available on the open market which are not only suitable, but nearly perfectly designed for the purpose of a fallout shelter communication system. It would appear, further, that the choice of location and method of mounting the antenna is a greater problem than the choice of antenna itself.

Certain antennas, which in themselves may well sustain 5 PSI without damage, are of a configuration which would result in thrusts exceeding 20,000 pounds at the mounting points under these conditions.

Since the important operating characteristics of the transmission lines are limited to attenuation and impedance, there appears to be no requirement for additional research in this field for the specific problem at hand. Transmission line is also available commercially which is perfectly adaptable to the systems contemplated. The choice of transmission line for an individual link will depend entirely upon the amount of allowable attenuation of the transmitted and received signals. Since the equipments will be designed with a characteristic input and output impedance of 50 ohms, a transmission line may be selected from this group which fits the needs of the individual station. In general, the least expensive line which offers the necessary attenuation characteristics will be used.

From the environmental standpoint, there seems to be but one requirement for transmission line. Normal installation techniques for transmission line result in clamps fastened to the wall which support the cable and hold it rigidly in place. It is anticipated that most installations will be in locations which have an inherent moisture or humidity problem. For this reason, it is imperative that some measure be taken to insure that deterioration of the transmission line does not occur during the storage phase. To avoid the corrosive action of dissimilar metals in moist atmosphere, jacketed transmission line should be specified, regardless of type. This will not inhibit standard grounding requirements, but will protect the transmission line regardless of path or structure.

A chart showing attenuation characteristics of four different qualities of 3/8" transmission line having a characteristic impedance of 50 ohms is shown on the following page.



ATTENUATION CHARACTERISTICS OF AVAILABLE 3/8" 50 OHM TRANSMISSION LINE

3.7 EMERGENCY POWER REQUIREMENTS

One of the most compelling needs in any emergency network is that of an adequate, economical, reliable standby power system which will function if and when the commercial or other main source of power fails. A great deal of attention has been given to this aspect of the contract since, as previously mentioned, it is almost certain that commercial power will fail at some point in time during the emergency confinement period.

It has been assumed that the emergency power supplies stipulated in the specifications contained herein will be used exclusively for the purpose of communications, and no other life-sustaining appurtenances have been considered in the choice of emergency power sources.

The features which seem most desirable in an emergency power supply are as follows:

1. It must be reliable.
2. It must be economical.
3. It must require no maintenance during storage periods.
4. It must be quickly activated.
5. It must be capable of operating the equipment for a 2-week period.
6. It must be readily replaceable during the emergency.

Rigid adherence to the requirements list above will quickly rule out motor driven rotating generators on perhaps five counts. Small generators do not have a reliability sufficient to expect 2 weeks' trouble-free operation. Fuel storage is a problem. Initial cost is high. They will require maintenance during storage, and they are not readily replaceable during the emergency period.

Mechanical generators which are operated by human power also leave much to be desired. At the time of commercial power failure, these

mechanical devices must be continuously supplied with manpower until the end of the confinement period to meet the listening requirements for the system. The possibility of a general lassitude settling upon the sheltered population cannot be overlooked in this regard. It is not certain that men can be compelled to operate such a device regardless of shelter condition. Moreover, it creates a problem of equitable distribution of the work load among the available shelterees.

Fuel cells appear to have characteristics which would fit most of the requirements. At this time, they are not economical, easily obtainable, nor are they readily replaceable.

Many other schemes have been considered and discarded because they failed to meet all the requirements for emergency power. We are left, therefore, with a stored energy system such as batteries.

Undoubtedly, sufficient dry batteries could be stored in a shelter to afford 2 weeks' operation. Dry batteries possess a finite shelf life unless special precautions are afforded them during the storage period. While it is possible that they may be readily replaceable in some areas (most drug stores carry a good selection of batteries in reasonable quantities), this premise does not hold on a nationwide scale.

One type of battery does meet the requirements with a degree of reasonableness. This is the 12-volt storage battery commonly utilized in automobiles.

Most transistors designed for high frequency, high power applications exhibit best efficiency at potentials in the vicinity of 25 to 50 volts DC. Our investigation has shown, as will be discussed in later sections, that efficiencies may be obtained which will allow operation at 12 volts while keeping within the maximum input power limitations required for 2 weeks'

operation. It is possible to purchase batteries with terminal voltages which better satisfy the requirements of the solid state techniques presently employed. Battery manufacturers have assured us that a departure from the common "Chevrolet type" battery will increase the initial cost by a factor greater than two. Thus, the economy of the situation borders on the intolerable. We have, therefore, chosen the ordinary 12-volt automotive type battery as the emergency power source for the equipment specified in this contract.

Additional efforts were expended to determine the best possible type of operation for the emergency power supply chosen. Two basic courses were open to pursuit. First, the batteries could be placed on charge when installed. This would eliminate the requirement of the equipment for operation from a 110 volt AC line altogether, thus creating an economic advantage. It appears that the savings in eliminating this feature, however, would be more than offset by the cost of charging apparatus. The most serious economic obstacle to this type of operation is maintenance.

It has been estimated that, with excellent maintenance procedures, such as bi-monthly inspections and water replacement, periodic dumping and recharging, the reliable life expectancy of a storage battery may be extended to approximately 5 years. The cost of maintenance of this quality for the batteries alone excludes this procedure from further consideration.

Dry charge batteries have features which satisfy all of the supply requirements provided simple protective features are specified at the time of purchase. The one factor which limits the life expectancy of a dry charge battery is contamination. Thus, if the cells are sealed against moisture, dust, etc., at the time of purchase, a life expectancy of approximately 10 years is assured. In addition, upon filling with the activator fluid (electrolyte)

these batteries will be capable of delivering approximately 75 per cent of rated charge immediately. After a short waiting period of perhaps an hour, such accumulation of plate coating as may have occurred during storage will have been dissolved and the battery will be capable of delivering nearly 100 per cent of rated capacity even after 8 or 10 years' storage time. Unfortunately, no exact empirical data exist for storage times of the length mentioned. These figures are based on actual tests of unsealed batteries after a period of 7 years.

As will be seen in the specifications, our investigation of the state of the art with respect to solid state techniques has convinced us that, with a 100 ampere-hour, 12-volt storage battery, the full requirements of transmit and receive will be met for the entire 2-week period considered and for the predicted duty cycle of transmit versus receive.

In the event that the duty cycle at a specific location exceeds the expected load and the battery deteriorates below an acceptable level, it is likely that the radiation level will have decayed to a point which will allow short-term excursions from the shelter without danger of excessive radiation doses to the personnel. It is almost certain that many abandoned vehicles which contain replacement batteries will be in the immediate vicinity of the shelter. Therefore, it seems reasonable to expect that replacement for the emergency power source could be obtained within 10 minutes should the need arise.

CHAPTER IV

EQUIPMENT AND SEMICONDUCTOR DEVICE AVAILABILITY

4.1 INTRODUCTION

When the general equipment requirements for a fallout shelter communications system were realized, discussions were held with leading manufacturers of 2-way communications equipment and semiconductor devices in order to make a determination of present equipment and device availability and probable future advances in the state of the art.

4.2 EQUIPMENT AVAILABILITY

At the present time, transistorized equipment is either in use or commercially available in all of the frequency bands of interest in this study. For the most part, however, this equipment is far more sophisticated than is necessary for a fallout shelter communications system and, consequently, unduly expensive for such an application.

At least two manufacturers offer a 1-watt transistorized transmitter-receiver which operates in the 150 mc band. One of these companies has a transistorized transmitter capable of 3 watts RF output in this frequency range. The receivers in all of these units have a sensitivity equal to or greater than that required for fallout shelter use. In addition to a 150 mc unit, one of these organizations also offers for sale a transistorized transmitter-receiver with an output of 250 milliwatts that operates in the 450 mc region of the spectrum.

A solid state transmitter with a rated output of 500 milliwatts at 950 mc has been developed by one of the manufacturers in the communications industry. It is basically an extension of the 3-watt, 150 mc transmitter discussed above followed by two added stages of varactor multiplication which

enables a reduced output at the higher frequency. This equipment was developed under a contract for a special purpose which is not directly related to 2-way voice communications and full information on its operation and cost is not yet available. The concepts employed could, however, be adapted for use in the shelter communications system.

All of this equipment makes use of the latest packaging techniques and miniature components are used extensively in the construction. The 150 mc and 450 mc units are of the hand-held portable type of equipment. Although dense packaging is not a requirement in the shelter system, the circuitry employed is applicable and the existence of these units points out that the overall technical objectives of this study can be realized today.

4.3 AVAILABILITY OF SEMICONDUCTOR DEVICES

Semiconductor devices which are capable of providing the output powers contemplated for the communications systems are now available, but most of the RF power transistors on the market today have been designed for optimum performance at higher voltage levels than that to be specified in this report. Many of these devices can, however, be employed at these lower voltages with moderately reduced transfer efficiencies.

4.4 FUTURE DEVICES AND CIRCUITRY

A critical factor in obtaining powers of 1 watt and more at frequencies over 150 mc through the use of solid state devices is the efficiency with which this has been done up to the present time. Since high frequency power transistors have not been available in large quantities, most of the power has been generated at lower frequencies and a loss in power has been absorbed during the frequency conversion process using non-linear diode devices. Power transistors capable of directly producing up to 4 watts at frequencies in the neighborhood of 450 mc are now being made available.

New transistor construction techniques, including changed geometrical arrangements of the elements, are being developed at the present time in efforts directed toward raising the power-versus-frequency barrier.

In addition to the different construction methods of the devices themselves, new circuitry techniques are being investigated which will improve frequency conversion efficiencies immensely. The application engineers of one transistor manufacturer have breadboarded an amplifier circuit which employs a power transistor as a power amplifier and variable reactance frequency multiplier simultaneously. This circuit has successfully produced an output of 4 watts at 580 mc.

Even though concentrated efforts are being made at the present time to produce high-frequency, high-power devices, the production of a transistor capable of directly generating radio frequency powers of any significance at 950 mc will not be achieved in the near future. The use of varactor devices for this purpose will still be applicable for the next couple of years.

Nevertheless, the representatives of all of the device manufacturers are unanimous in the opinion that the objectives sought in this project can be realized today and will be realized more efficiently, from the standpoints of power consumption and costs, within the next 2 or 3 years. Because of the recent history in technological advancements, no one is offering a prediction beyond 3 years.

CHAPTER V

COST ESTIMATES
FOR FALLOUT SHELTER COMMUNICATIONS

5.1 INTRODUCTION

During the meetings conducted with representatives of the manufacturers of communications equipment and solid state devices, discussions were held concerning the probable costs of the equipment envisioned in this project. In general, these people were, understandably, reluctant to give definite price breakdowns and pointed out the difficulty of assigning cost figures for the production of special purpose equipment at this early planning stage. In an effort to clarify the requirements, tentative electrical specifications were drafted and prices for units in lots of 10,000 were discussed. Based on the study area, for which a plan exists contemplating 670 shelters and therefore more than 700 pieces of equipment, an order of 10,000 units appears to be practical.

5.2 COST INFORMATION OBTAINED FROM EQUIPMENT
MANUFACTURERS DATA

The initial information received from manufacturers of transmitter-receiver devices indicates that the equipment, when ordered in lots of 10,000, will cost between \$300 and \$700, with the higher figure being applicable for the 950 megacycle units. This anticipates a reduction over conventional miniaturized equipment. The lowest estimate obtained was offered by a manufacturer who suggested a trade-off between RF power output and receiver sensitivity. Such a trade-off would make the equipment specifications almost identical to the performance characteristics of some of that manufacturer's communications equipment which is, incidentally, being marketed today. For the most part, however, no advantages

in the overall system, i.e. performance versus cost, would be realized from this trade-off and a degradation would occur at the higher frequencies. Estimates based on this suggestion ranged from \$300 to \$450. Notwithstanding this concept, it is felt that the equipment manufacturers have been overly conservative (from their viewpoint) and may have overlooked some cost saving techniques.

Some of the techniques have been mentioned earlier, for example, using a ratio detector in the receiver, the possible use of a combination microphone-speaker, and the use of standard size, rather than miniature, components. Another possible cost saving technique which should be considered by the manufacturers is the evolution of a family of equipment which shares a common parent. For instance, a transmitter may be designed for service at 150 mc which will deliver the required power output and deviation. The addition of multipliers will allow operation at increased deviation at 450 mc and 950 mc at less power output. Efficiencies in multipliers are such today that the required power output at the higher frequencies may be realized through this technique.

Similarly, a basic receiver for the 450 mc service may be designed which meets all the specifications required. The addition of another front end will convert the receiver for use at 950 mc and still maintain the required bandwidth and other operational parameters. Unfortunately, narrow-band requirements in the frequency ranges and services contemplated will not allow the basic receiver at 150 mc to be utilized as the prime antecedent unless crystal filters are utilized to limit bandwidth. This approach to bandwidth is generally more costly, but a trade-off may be accomplished which might make it economically feasible to pursue this possibility. If a common parent at 150 mc can be devised and utilized at sufficiently low

cost to allow the use of crystal filters, this certainly should be considered by the manufacturer during the developmental stage.

Based on some of these techniques and the information obtained from device manufacturers, it is felt that a reduction in the above price estimates can be expected.

5.3 COST INFORMATION OBTAINED FROM SEMICONDUCTOR MANUFACTURERS

The manufacturers of solid state devices were a little more candid in their price estimates and suggestions. One manufacturer pointed out the possibility of realizing a savings if the additional cost of a larger power supply were traded off against using a smaller number of transistors and obtaining a higher conversion efficiency. However, a full exploration of this idea demonstrated that no significant savings would be realized and the added power supply replacement difficulties would militate against its adoption.

The suggestion of another manufacturer proved extremely helpful in making a cost estimate. It was pointed out that this equipment could be manufactured using "kits" containing "fallout" devices at a greatly reduced cost to the equipment manufacturer. A "fallout" device is a product which has failed to achieve all of the performance characteristics of a particular type but is still perfectly capable of being used in a circuit. For example, a transistor which is produced as part of a run of a type guaranteed for 10 db power gain that only provides 8.5 db power gain is a "fallout" device. A "kit" is a number of transistors which have been pre-tested and are guaranteed, if used together, to achieve the performance required. This manufacturer's estimate of the cost per kit of these devices guaranteed to provide 1 watt at 950 mc. based on an order of 10,000, is \$25 to \$30.

The cost of a string of regular devices which are capable of this performance is approximately three times this figure. As the production numbers and demands for the devices increase, the price will decrease. For example, a power transistor which sold for over \$100 less than three years ago now costs less than \$40.

5.4 ESTIMATED COST OF THE SHELTER COMMUNICATIONS EQUIPMENT

On the basis of the information obtained from the equipment and device manufacturers, it is estimated that the equipment to be used at 150 mc will cost approximately \$250 per transmitter-receiver. The 950 mc equipment will cost approximately \$300. These figures assume orders in lots of 10,000 and include what is felt to be an adequate amount over the cost of materials and production to insure a reasonable profit for the manufacturer. This price is expected to decrease slightly, but not substantially, during the next three years. The developmental and engineering costs for this equipment cannot be estimated but it is felt that, for a program of this scope, such costs will be insignificant. No prognosis beyond three years can be offered due to the rate of technological advancement in this field.

Sealed, "dry charge" storage batteries, including the electrolyte, will cost approximately \$15 per transmitter-receiver. The cost of each antenna will depend upon the type contemplated and the frequency at which it will be used but is expected to lie in the range between \$10 and \$100 per shelter. A price break due to ordering in large quantities is expected when purchasing transmission line and, depending on the type and quality used, this will cost between 10¢ and 45¢ per foot.

The total cost of the hardware (transmitter, receiver, antenna, transmission line) for a given shelter will vary between a minimum of \$280 at 150 mc to a maximum of \$420 at 950 mc. The specific cost of each com-

plete station will be dependent upon the frequency and path length involved and the measures which must be taken during the installation to provide satisfactory communications over its particular path.

CHAPTER VI

CONCLUSIONS

The concept of a radio back-up to a primary landline fallout shelter communications system utilizing solid state techniques and having the ability to continue operation even though commercial power fails is technically feasible today.

The equipment operational requirements which have evolved from the studies and calculations made during the course of this contract are considered conservative and are based on sound engineering practices and current techniques. This moderate approach was adopted because of the extremely broad scope of the project in terms of a nation-wide system concept. Realistic propagation losses, transmission line losses, and antenna gains have been used to determine the parameters of the system based on minimum and maximum path lengths in the various frequency bands.

In many cases, the performance characteristics will be less severe than those indicated by the theoretical calculations. In some cases, the requirements will be more severe. In almost every case, however, techniques and equipments are available to overcome the equipment deficiencies and to fit the units to the individual case.

A major item of basic hardware cost is reflected in transmission line and antennas. As of today, the evolution of transmission lines and antennas for service of the type required has reached a fairly high state. We have concluded that a sufficient variety of antennas and feed lines exist which are particularly suited to the requirements and environment expected. As indicated in the section dealing with cost analysis, a considerable range

of prices exists for external hardware in each of the frequency bands. This is the one area in which the cost of an actual installation could be reduced. For instance, good engineering practice indicates the use of type "N" connectors at the higher frequencies, 450 mc and 950 mc. This is based on impedance mismatches which occur at the higher frequencies with the more conventional type connectors. Field tests of prototype equipments may well prove that less expensive connectors and line may be tolerated in a large number of applications.

The study has shown that equipments can be designed and built specifically for the purpose of fallout shelter communications systems at less than half of the cost of existing equipments which may be utilized for this purpose. For instance, solid state equipments at 150 mc, currently marketed, which could be used for the purpose are priced at more than twice the projected costs for units designed for fallout shelter communications. In this context, an element of significant savings has been demonstrated.

CHAPTER VII

SPECIFICATIONS

7.1 PURPOSE AND SCOPE

The purpose of these specifications is to set the minimum mechanical standards and operating characteristics for frequency modulated transmitter-receivers for use in a national fallout shelter communications program.

Equipments for this service must be capable of type acceptance by the Federal Communications Commission for operation in the Safety and Special bands allocated frequencies. In general, three separate equipments are represented in the specifications in that operation will be required in the region of 150 mc, 450 mc, and 950 mc.

The specifications contained herein have been evolved from a comprehensive study of the problem. Because of the nature and scope of the overall objectives, presently available equipment capable of surpassing the performance requested, while technically attractive, is not economically feasible for this purpose. The magnitude of the concept of a nationwide fallout shelter program is such, however, that developmental costs for equipment specifically tailored to the project will be rather insignificant.

7.2 GENERAL CONSTRUCTION

A. Materials and components

The materials and components used in the construction of the equipments specified shall be of adequate quality to insure compliance with the specified operating characteristics under the conditions outlined. To the greatest extent practicable, nonflammable materials will be utilized throughout, and materials, components, and insulation will be utilized which, upon failure or charring, will not generate fumes which are obnoxious or detrimental to the health of humans in a confined space.

Components utilized in this equipment, with the exception of semiconductor devices, may be operated up to 100% of the continuous duty rating for the item, but in no case will a component, by reason of design or accident, be inserted in a circuit which will cause the maximum continuous duty rating to be exceeded.

Semiconductor devices used in the equipments must be rated such that operation in accordance with the stated duty cycle will cause no degradation of the performance of the equipment, and the life expectancy of the devices will not be jeopardized by such operation.

B. Component Size

No effort will be expended toward miniaturization of the equipments. No special miniaturized components will be utilized where less costly standard sized components will otherwise meet the requirements.

C. Equipment Layout

The mechanical and electrical design of the equipment will be such as to facilitate maintenance of the equipments. Construction techniques which require the removal of components in order to replace or test other components will be unacceptable.

7.3 GENERAL REQUIREMENTS

A. Type acceptance

The equipments specified herein must comply with all applicable rules and regulations of the Federal Communications Commission insofar as they concern the acceptance and license capabilities for the service intended.

B. Instruction Manuals

Instruction manuals are to be written such that the average radio technician can read and interpret effectively the contents. These

manuals will be comprehensive and will include the following minimum sections:

1. Complete description of operation.
2. Complete schematic diagrams.
3. Interconnection diagrams.
4. Complete tuning and alignment procedures.
5. Installation instructions.

One instruction book will be packed in the carton with each unit of equipment furnished.

C. Safety Requirements

The equipments specified will be constructed mechanically and electrically so as to meet the requirements of the National Board of Fire Underwriters.

D. Use of Metals

Protective treatment shall be applied to inner surfaces and component parts of the equipment subject to corrosion detrimental to mechanical and electrical performance. Prior to painting, steel parts must be properly bonderized, copper-plated, or treated with other suitable rust-retarding process. Plating shall not be applied to parts where an undesirable electrolytic reaction may alter the serviceable efficiency of the resulting bimetallic contact.

All metallic parts or items, other than corrosion-resisting steels, Monel metal, aluminum and aluminum alloys, and the like, shall be cadmium, copper, zinc, chromium, nickel, or silver plated by electroplating, or shall be bonderized and painted with suitable corrosion-resistant paints, in accordance with good engineering practices. Copper alloys need not be so coated where their function will not be impaired

by the omission of the coating. Welded or soldered items or parts fabricated from sheet iron or steel, such as power transformer cases, shall be so coated after all welding or soldering operations. Tin plating will be permitted in lieu of other special platings, in such instances where soldering forms a final assembly operation, as in the sealing of a transformer case or similar item. Items or parts which require forming operations in fabrication shall be so coated after completion of all such operations. All such coating shall be uniform in thickness, have good adherence, and be of the similar quality, thickness, and adherence as is used in good commercial practice for equipment of this type.

Nonferrous metals shall be employed in the construction whenever practicable, particularly with respect to the radio frequency portions of the equipment. This requirement also applies to metallic fasteners, including bolts, screws, nuts, and washers. When ferrous materials are used in terminals and fasteners carrying low frequency or direct currents, they shall be suitably plated to provide proper electrical contacts and corrosion-resisting qualities.

Contact between dissimilar metals in the production of the equipment shall be avoided. When it is impracticable to provide an alternate for the use of dissimilar metals, the adjacent surfaces shall be separated by electroplating commensurate with good engineering practice. The use of corrosion-resisting steel or Monel metal in direct contact with metals and/or alloys other than aluminum is acceptable.

E. Performance Standards

All communications equipment, associated accessories, and their component parts shall meet or exceed the latest standards specified

by the Electronic Industries Association (EIA), unless otherwise specified herein.

7.4 DETAILED REQUIREMENTS

A. Equipment Enclosure

The enclosure for all equipments detailed in this specification shall be constructed so as to be interchangeable between units regardless of frequency band and shall contain the transmitter and receiver. This enclosure shall be of the drawer type to allow the front panel and chassis to be removed by sliding forward. The top shall be removable and shall be held in place by suitable lips on the front panel and rear panel of the enclosure. The entire assembly will be capable of being closed and latched for transport. NO KEY LOCK WILL BE UTILIZED FOR THIS PURPOSE.

Perforations or ventilation holes will not be permitted. Heat dissipation must be accomplished by appropriate heat-sinking and the equipment must be impervious to dust. Perforations will be allowed in the front panel to accommodate the loudspeaker and/or microphone. The speaker and microphone must, however, be attached to the front panel in such a manner as to exclude dust from penetrating the interior chassis compartments.

The housing shall be finished in accordance with existing Office of Civil Defense (OCD) specifications as to color and insignia.

B. Identification Label

Each unit shall bear a suitable metal plate or other permanent identification label which displays the following information.

1. Model number.
2. FCC type number.

3. Serial number.

4. Frequency.

5. Power output.

C. Controls and Indicators

Each control available to the operator shall have its functions suitably designated by means of a metal plate, engraving in the panel, or silk screen marking on the panel. The following controls and indicators shall be provided:

1. A push-to-talk or transmit/receive switch. This switch shall be of the rotary type with wiping contacts. The activator arm shall be a lever similar in shape and appearance to the type commonly employed in office intercom units. This switch will perform the function of transferring the supply voltage from the receiver to the transmitter and vice versa.
2. A combination off-on switch and volume control will be available on the front panel.
3. A squelch adjustment may be available at the front, but will not be fitted with a knob or long shaft. This adjustment, if available at the front, will be a screwdriver adjustment.
4. A neon bulb will serve as pilot light when operating from 115-volt AC sources. No pilot indicator will be available when operating from the 12-volt DC source.
5. A neon bulb, or other indicator, shall be provided which will tell the operator when the transmitter is operating. The input power to this device shall be controlled by the push-to-talk switch mentioned above.

D. Connectors

Only two connectors are required for the operation of this unit. The antenna connector will be affixed to the front panel or front panel lip and shall be a standard chassis-type female connector. At 150 mc this connector may be a UHF type of the S0239 variety. At the higher frequencies, the antenna connector must be type "N" or equivalent so as to assure a good impedance match to the transmission line.

A jack to accept the plug on a low impedance earphone (single or double) shall be mounted in the front panel. This jack will contain a pair of normally closed contacts for the purpose of disconnecting the loudspeaker when the earpiece plug is inserted in the jack.

E. Metering

All appropriate metering points in the transmitter and receiver will be terminated in a multi-contact, keyed socket on the front panel. Metering will be accomplished using an external meter with switch positions.

No panel-mounted meters are required.

F. Accessories

The accessories shall consist of a single earpiece, cord, and plug of the low impedance type. The earphone shall be affixed to an adjustable headband. Tinsel wire may be used provided it is sheathed with a suitable woven cloth or plastic flexible covering, and provisions are made to mechanically affix the cord to the earpiece and plug to avoid breaking the wires. The plug shall be standard size.

G. Microphone-Speaker

The microphone and/or speaker shall be panel mounted. The cone of the loudspeaker shall be so constructed or so treated as to be

moisture resistant during storage periods and use in areas of high humidity. There is no objection to utilizing the loudspeaker as a microphone provided a transducer of suitable quality is chosen so as to meet the transmission and receiving distortion specifications listed.

H. Adjustments

Wherever possible, the mechanical design shall allow all tuning adjustments to be made from the top of the chassis. A suitable adjustment will be incorporated for the purpose of adjusting the level of modulation in the transmitter. Warming capacitors shall be included for the purpose of fine frequency adjustments in the transmitter and receiver.

I. Relays

A relay for the purpose of switching the antenna from the receiver to the transmitter will be incorporated. This relay will be suitably sealed from the effects of dirt and moisture so as to preclude corrosion of the contacts during long storage periods in unfavorable environments. No other relays are considered necessary to the operation of the equipment.

J. Duty Cycle

The transmitting equipment specified herein shall be capable of the following duty cycle without degradation in the power output:

1 minute on, 1 minute off for 15 minutes; then 1 minute on, 4 minutes off for 8 hours.

The receivers in all units shall be capable of continuous operation.

K. Power Source

The equipments described in this specification must be capable of operating from a 117-volt AC line or a 12-volt DC storage battery. The transmitters must suffer no more than 3 db performance degradation

while operating from the AC line with line voltages between 105 and 130 volts AC. The design center for storage battery operation shall be 12.8 volts. Not more than 3 db transmitter degradation will be allowable with plus or minus 10% DC voltage variation. The frequency stability must be maintained as specified herein over a variation of plus or minus 15%.

L. Cabling and Wiring

The units described herein shall be fitted with an AC attachment cord not less than 10 feet in length. Battery cables shall be not less than 6 feet in length and shall be fitted with 50 ampere battery clamps or equivalent. Battery clamps will be sheathed in suitable insulating sleeves and color coded as to polarity. A suitable method of coiling, or otherwise storing, the battery cables will be incorporated on the rear of the equipment housing.

Internal cabling or wiring will be neatly harnessed in accordance with good engineering practice. Cabling between boards will utilize soldered terminations.

M. Climate Conditions

The equipments specified herein shall be capable of operation in areas where the temperatures may vary from minus 30° C to plus 50° C and under conditions where the relative humidities range from 0 to 95%.

N. Moisture Absorption

The substrates of printed circuit boards for the equipment described shall be of a type which exhibits high resistance to long-term moisture absorption. The use of paper coil forms is not acceptable. Coil forms must exhibit the same high resistance to moisture absorption as indicated above. Any components which utilize paper for covering or

insulation must be treated so as to withstand the effects of moisture under storage conditions. The finished boards will be treated with moisture resistant lacquer or a suitable moisture resistant substance to inhibit corrosion of circuitry and soldered connections.

O. Circuit Boards

Because of the possibility of long storage periods under conditions which foster corrosion, etc., plated through holes will not be acceptable. Eyelets will be utilized, and the construction techniques employed for insertion of the eyelets will reflect the latest research in this area. Funnel-type eyelet insertion which allows the free flow of solder around the eyelet is an example of newer techniques. All semiconductor devices employed in these units will be permanently soldered, and the use of sockets for this purpose will not be acceptable.

P. Measuring Techniques

The measurements employed to determine the electrical operating characteristics of the units specified will be those applicable measurement techniques specified by the Electronic Industries Association for equipment of this type.

7.5 ELECTRICAL OPERATING CHARACTERISTICS

It is the purpose of these specifications to set forth the minimum electrical operating requirements for Frequency Modulated narrow-band radio transmitters and receivers capable of providing two-way voice communications in a national fallout shelter communications program.

The equipment shall be capable of simplex operation on one of the frequencies specified in Subpart E of Part 89 of Subchapter D of the Federal Communications Commission's Rules and Regulations in either the 150 mc, 450 mc, or 950 mc regions.

A. Transmitter Requirements

	<u>153-159 mc</u>	<u>453-459 mc</u>	<u>952-960 mc</u>
Minimum RF power output	3 watts	1 watt	1 watt
Output impedance	50 ohms	50 ohms	50 ohms
Maximum DC input power from 12-volt source (watts)	20	30	25
Frequency stability of carrier from -30° C to +50° C	0.0005%	0.0005%	0.0005%
Spurious and harmonic emission attenuation	50 db	43 db	43 db
Maximum modulation deviation	±5 kc	±15 kc	±15 kc
Maximum bandwidth	20 kc	40 kc	40 kc

Audio frequency response. The audio frequency response shall not vary more than +1 or -3 db from a true 6 db per octave pre-emphasis characteristic from 300 - 3000 cps as referred to the 1000 cps level.

Distortion. The audio frequency harmonic distortion shall not exceed 10% at 1000 cps for 2/3 of maximum deviation.

FM hum and noise level. The FM hum and noise level shall be 40 db below a modulation of 1000 cps for 2/3 of maximum deviation.

Modulation. Each transmitter, having a final power amplifier supplied with greater than 3 watts DC input power, shall be provided with a device which will automatically prevent a modulation deviation greater than that specified above. Each such transmitter shall also be provided with a low-pass audio filter, installed between the modulation limiter and the modulation stage, which meets the following specifications:

At audio frequencies between 3 kc and 15 kc, the attenuation shall be greater than the attenuation at 1 kc by at least $40 \log_{10} (F/3)$ db, where F is the audio frequency in kilocycles.

B. Receiver Requirements

	<u>153-159 mc</u>	<u>453-459 mc</u>	<u>952-960 mc</u>
Sensitivity for 20 db receiver quieting	1 uv	2 uv	4 uv
Threshold sensitivity of squelch	0.35 uv	0.8 uv	1.5 uv
Frequency stability from -30°C to +50°C	0.0005%	0.0005%	0.0005%
Modulation acceptance bandwidth at -6 db	±5 kc	±15 kc	±15 kc
Adjacent channel selectivity for 12 db SINAD	60 db	60 db	60 db
Spurious response attenuation	70 db	70 db	70 db
Intermodulation response attenuation	50 db	50 db	50 db
Input impedance	50 ohms	50 ohms	50 ohms
Hum and noise ratio	40 db	40 db	40 db

Audio power output. There shall be sufficient audio output power when driving a 3.2 ohm loudspeaker to insure a sound level of 80 db above 0.0002 dynes per square centimeter at a distance of 10 feet from the loudspeaker when measured on a General Radio Type 1555-A Sound-Survey meter, or its equivalent. The audio output power used to drive a low impedance headphone shall be a minimum of 10 milliwatts.

Distortion. The maximum distortion of the receiver at 1000 cps modulation shall be 15% when the loudspeaker is in use at rated output and 10% when the headphones are in use at full volume.

Audio frequency response. The audio response of the receivers shall not vary more than +2 to -3 db when the loudspeaker is used, and should not vary more than +1 to -3 db when the headphone is used, from a

standard 6 db per octave de-emphasis curve over the frequency range of 300 to 3000 cps, as referenced to 1000 cps.

Oscillator radiation. The receivers shall comply with Subpart C of Part 15 of the Rules and Regulations of the Federal Communications Commission.

DC input power. The maximum DC input power for the receiver shall not exceed 500 milliwatts.

CHAPTER VIII

RECOMMENDATIONS

The specifications for the equipments required under the contract have been evolved from a comprehensive study of the requirements, environmental conditions, operational problems, and cost analysis standpoints. From the engineering standpoint, we have attempted to be conservative within the framework of good engineering practices, but always looking toward the acquisition of quality equipments designed for the particular job and the minimum cost.

The cost figures contained in the report represent the best judgment based on device costs and manufacturer's practices. There is, however, an element of latitude left to the contractors to take advantage of cost savings techniques. Because of this latitude, actual costs figures may vary somewhat once a suitable prototype unit has been constructed.

Moreover, tests of prototype units may show areas of even greater cost reduction. In addition, a true evaluation of the equipments is in order to insure compliance with the specifications, and an analysis of the equipments under field conditions will result in units best suited to the particular job.

It is recommended that a developmental contract be issued which results in the procurement of four (4) complete units in each frequency band. This number will be sufficient to conduct tests designed to prove the efficiency and suitability of the units and compliance with the specifications.

It is also recommended that a test program be established for the purpose of a thorough evaluation of the equipments.

BIBLIOGRAPHY

- Bullington, Kenneth. "Radio Propagation Variations at VHF and UHF." Proceedings of the IRE, 35:27-32 (January, 1950).
- Carroll, John M., et al. Modern Transistor Circuits, Chapter 1, Pages 1-3. New York: McGraw-Hill Book Company, 1959.
- Civil Defense, United States Office of. Fallout Shelter Surveys: Guide For Architects and Engineers. Washington, D.C.: United States Office of Civil Defense, 1960.
- Collins Radio Company. Final Report on Study Program for Hardened HF, VHF and UHF Antennas. Dallas: Collins Radio Company, 1963.
- Gautney and Jones. Fallout Shelter Communications Study. Washington, D.C.: Gautney and Jones, 1962.
- Glasstone, Samuel, ed. The Effects of Nuclear Weapons. Washington, D.C.: United States Atomic Energy Commission, 1962.
- Harifan, Donald T., et al. Physiological and Psychological Effects of Overloading Fallout Shelters. Santa Monica: Dunlap and Associates, Incorporated, 1963.
- International Telephone and Telegraph Corporation. Reference Data for Radio Engineers. 4th ed. New York: American Book-Stratford Press, Incorporated, 1956.
- Jasik, Henry, ed. Antenna Engineering Handbook. New York: McGraw-Hill Book Company, 1961.
- Kaylie, H. L. The Design of Varactor Frequency Multipliers for Mobile Communications, paper presented to PGVC-IEEE. Dallas: Ampere Electronic Corporation, 1963.
- Pulfer, J. K., and A. E. Lindsay. "Simultaneous Amplification and Parametric Frequency Multiplication in VHF Power Transistors." Proceedings of the IEEE, 52:212 (February, 1964).
- Terman, F. E. Radio Engineering. New York: McGraw-Hill Book Company, 1947.
- Vogt, G. A. A Low Power Crystal Oven, paper presented to PGVC-IEEE. Charlottesville: Ovenaire, Incorporated, 1963.
- "1964 -- The Year Microcircuits Grew Up." Electronics, 37:10-11 (March 13, 1964).

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Gautney & Jones, Consulting Engineers, Washington, D. C.
Office of Civil Defense, Department of Defense,
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Consideration is given to those aspects of shelter pro-
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